Operational Amplifiers

ME 6405, Fall '04

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Operational Amplifiers

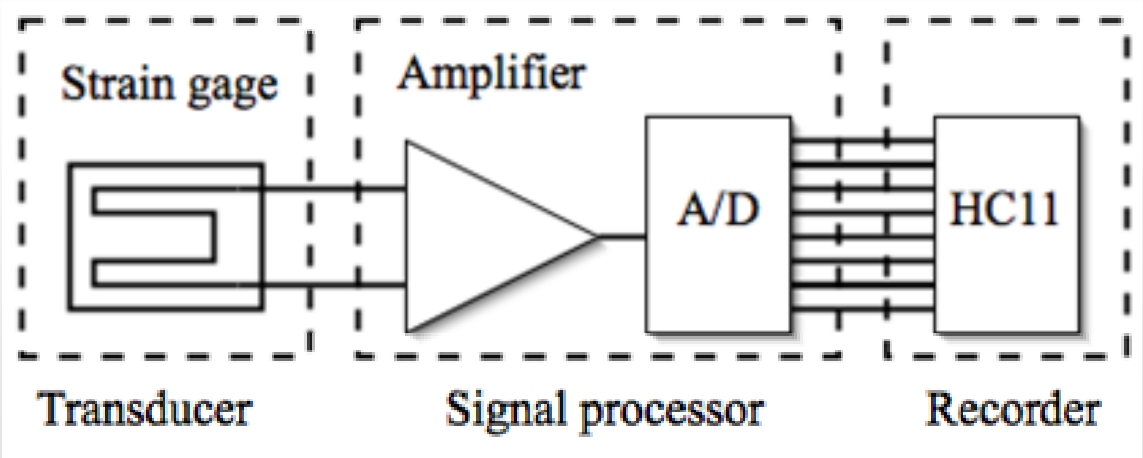
Goals:

- Introduction
- Characteristics
- Types
- Models VS. reality

Introduction

Most transducers provide analog signals:

- **Too small**
- **Too noisy**
- Wrong information
- DC offset

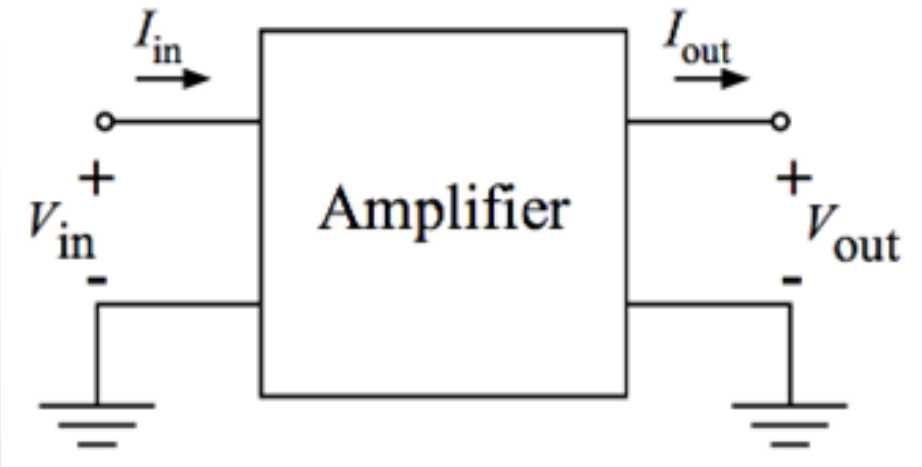


Measurement system

Amplifiers

- **Ideally: Increase amplitude without affecting other properties of the signal**
  - Voltage gain:

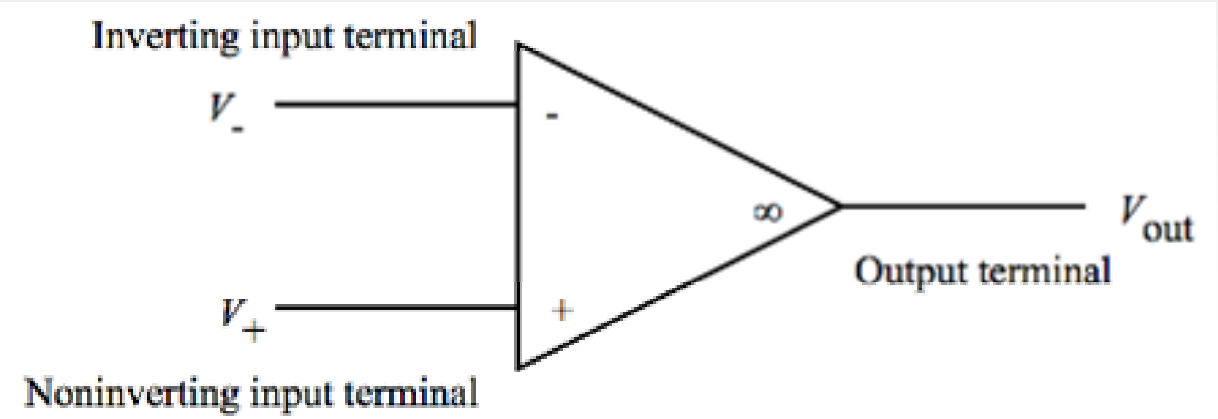
$$A_v = \frac{V_{out}}{V_{in}}$$



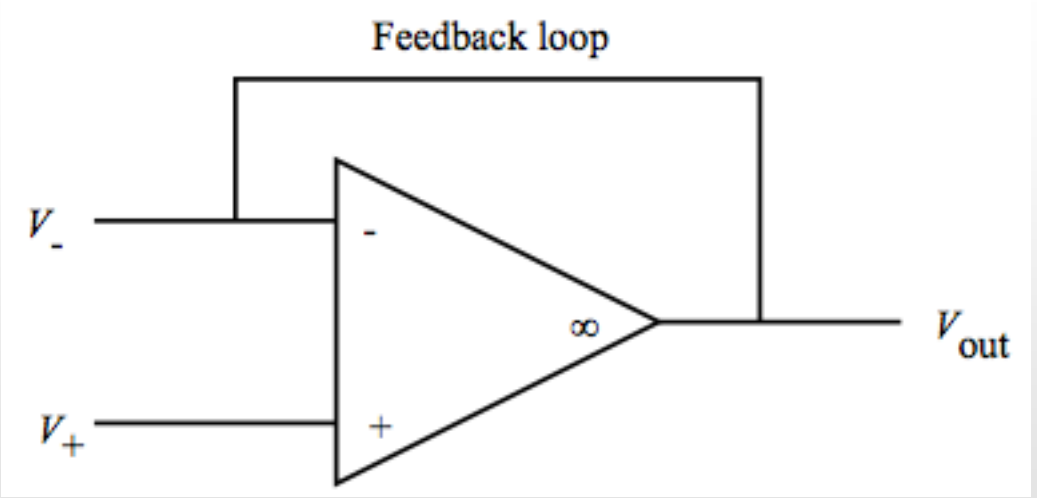
  - Impedances:

$$Z_{in} = \frac{V_{in}}{I_{in}} \qquad Z_{out} = \frac{V_{out}}{I_{out}}$$

Terminology



Open loop

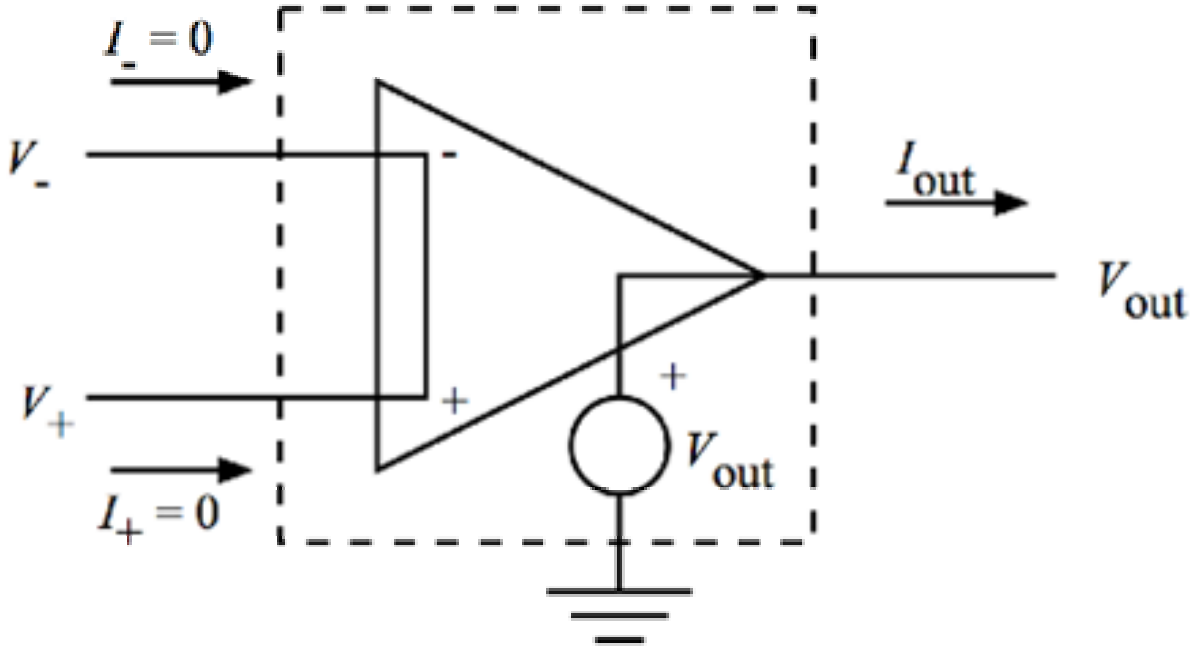


Closed loop → Stabilized signal

Ideal Model

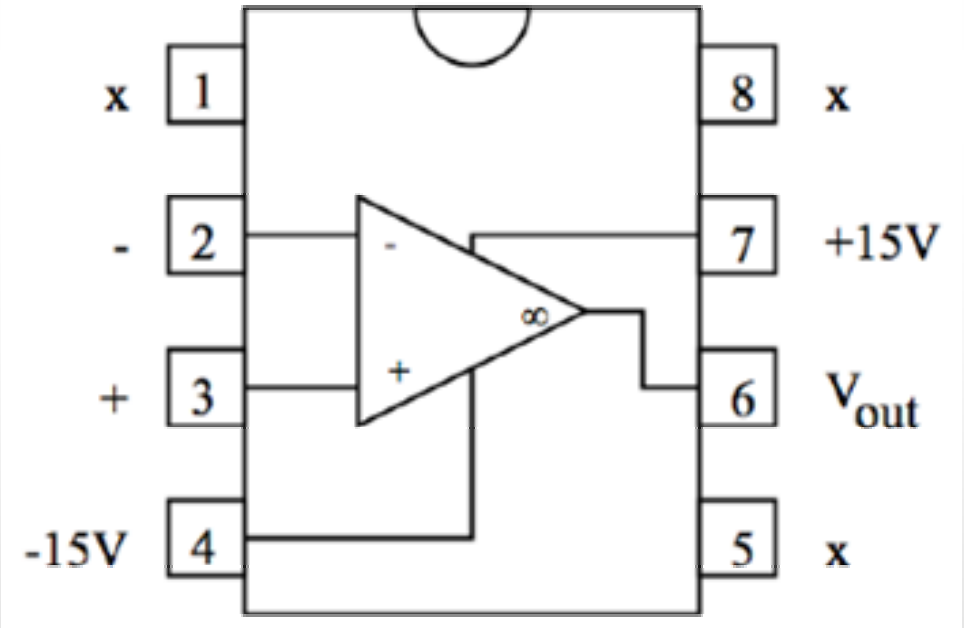
- Aid in circuit analysis

1. $\mathbf{I_+ = I_- = 0}$
2. $\mathbf{V_+ = V_-}$
3. $\mathbf{Z_{out} = 0}$



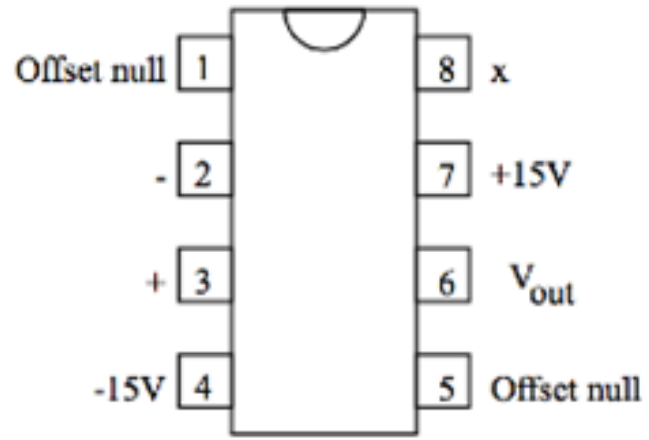
Configuration

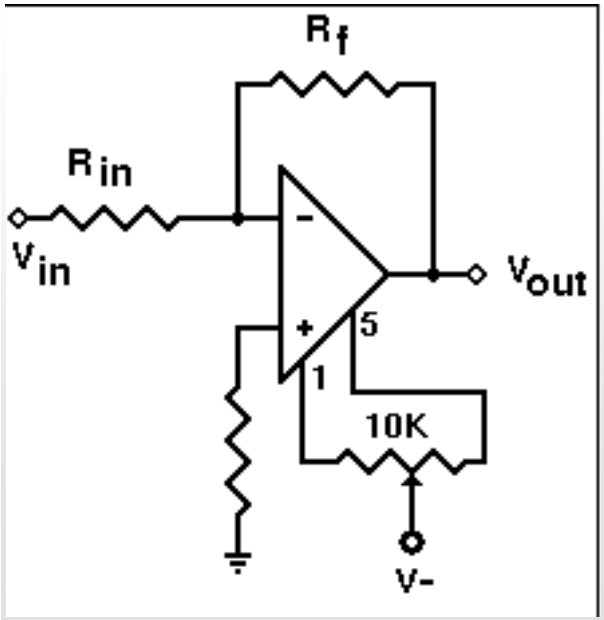
- 741 General purpose amplifier

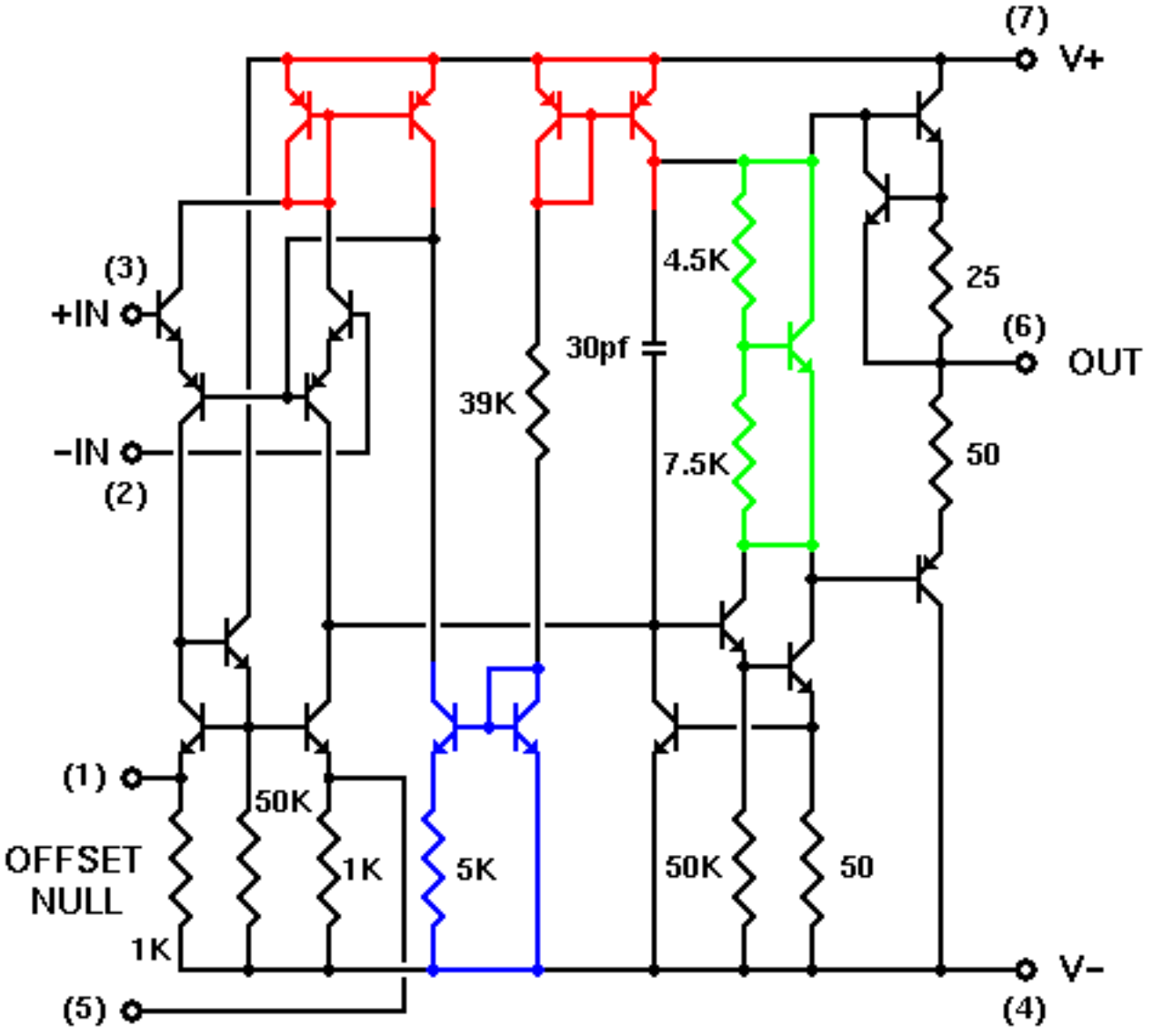


Pin-out

Internal design

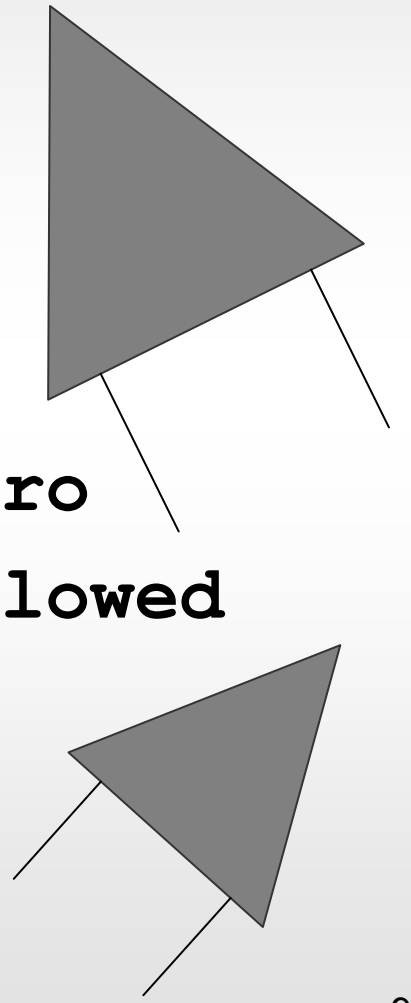




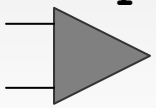


The Ideal Op-Amp

- Infinite Input Resistance
- Zero input current
- Zero Output Resistance
- Infinite Gain
- Common Mode Voltage Gain Zero
- Zero Noise / Zero Output Allowed
- Unlimited Bandwith
- Temperature Independent



Ideal v. Real Op-Amps

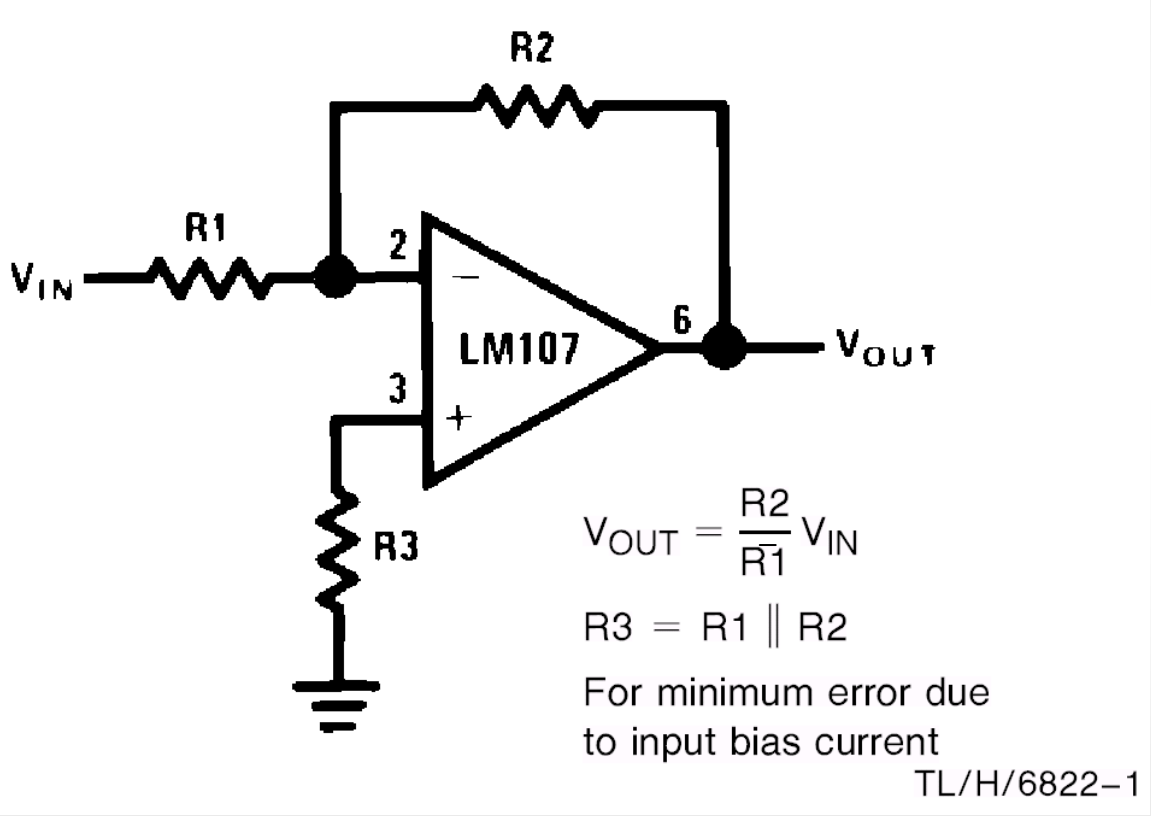
	Ideal Op-Amp 	Typical Op-Amp 
Input Resistance	infinity	$10^6\ \Omega$ (bipolar) $10^9\ \Omega$ - $10^{12}\ \Omega$ (FET)
Input Current	0	10^{-12} – 10^{-8} A
Output Resistance	0	100 – 1000 Ω
Operational Gain	infinity	10^5 - 10^9
Common Mode Gain	0	10^{-5}
Bandwidth	infinity	Attenuates and phases at high frequencies (depends on slew rate)
Temperature	independent	Bandwidth and gain

http://hyperphysics.phy-astr.gsu.edu/hbase/electronic/opampcon.html#c1

Op-Amps for Math

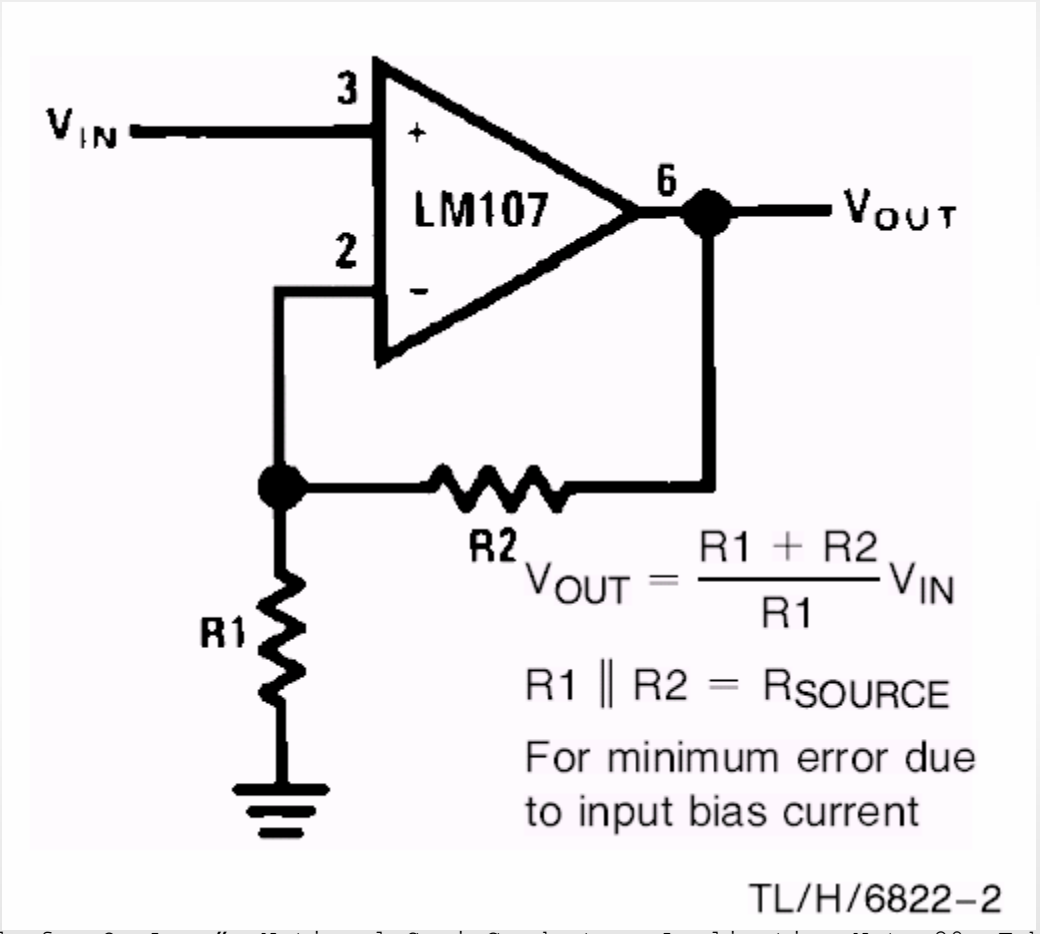
- Inverting
- Non-Inverting
- Summing
- Differencing
- Integrating
- Differentiating

Inverting



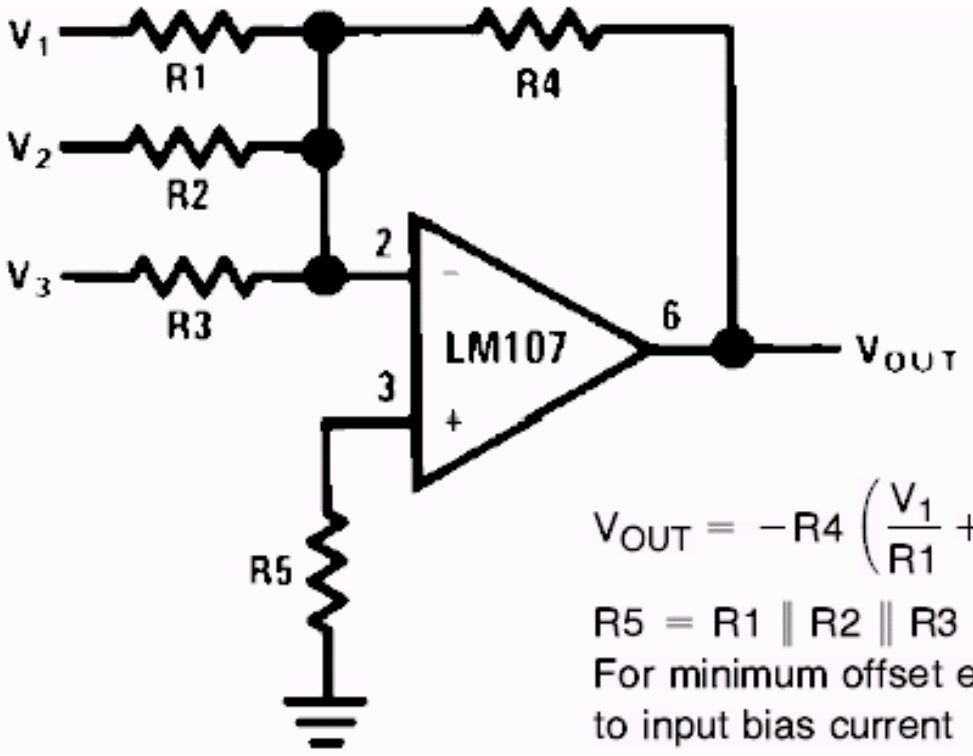
"An Application Guide for Op-Amps", National Semi-Conductor, Application Note 20, February 1969.

Non - Inverting



"An Application Guide for Op-Amps", National Semi-Conductor, Application Note 20, February 1969.

Summing Op-Amp



$$V_{OUT} = -R4\left(\frac{V_1}{R1} + \frac{V_2}{R2} + \frac{V_3}{R3}\right)$$

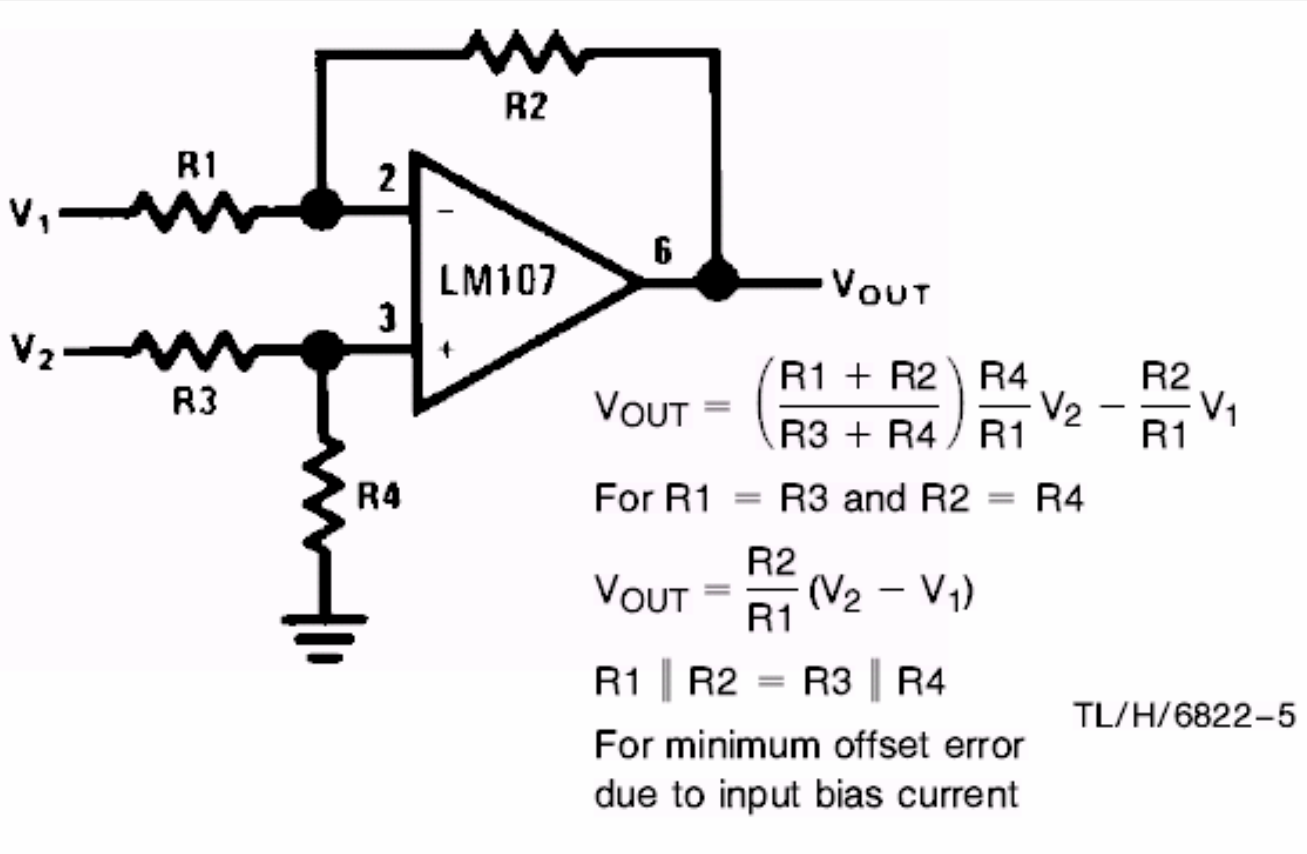
$R5 = R1 \parallel R2 \parallel R3 \parallel R4$

For minimum offset error due to input bias current

TL/H/6822–4

"An Application Guide for Op-Amps", National Semi-Conductor, Application Note 20, February 1969.

Differencing Op-Amp



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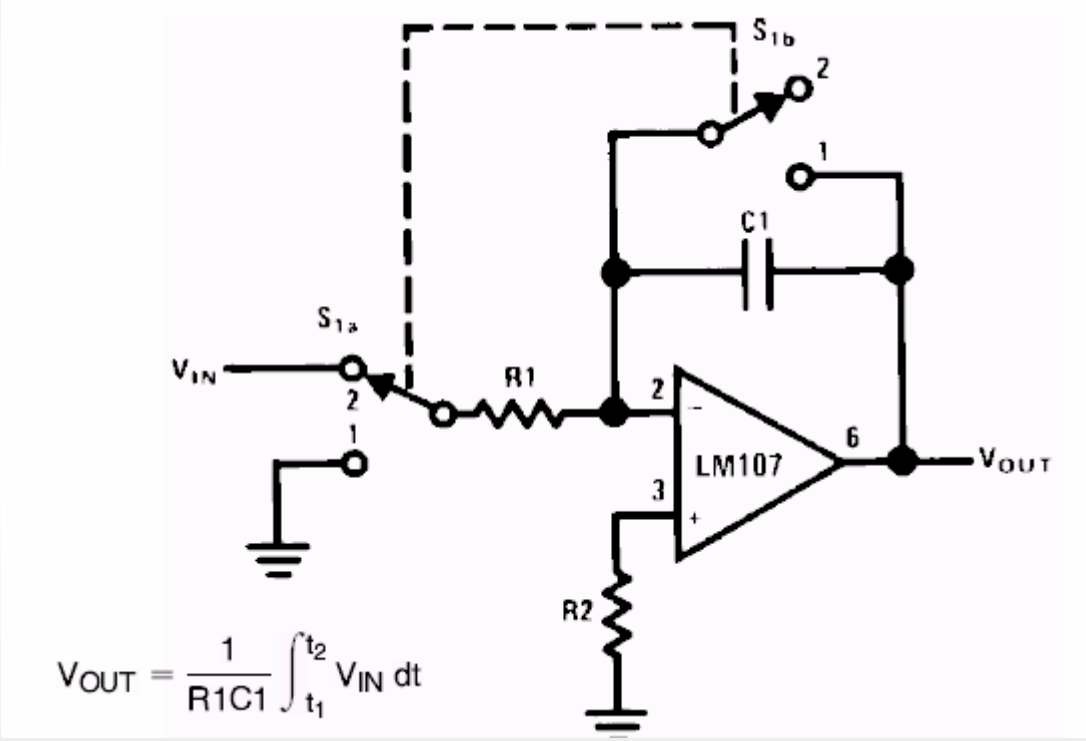
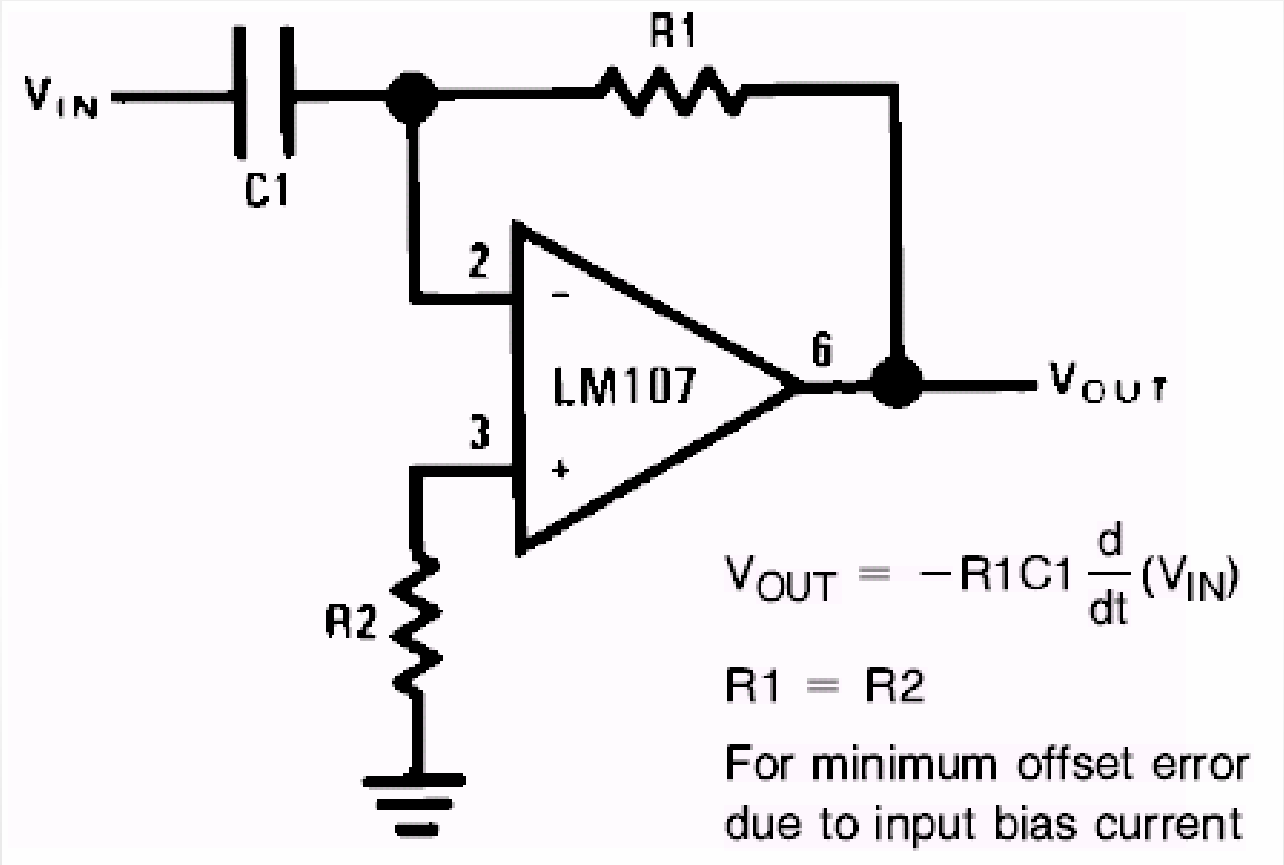
Integrating Op-Amp



"An Application Guide for Op-Amps", National Semi-Conductor, Application Note 20, February 1969.

Differentiating Op-Amp



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Use of an Op amp

- **Filters:**

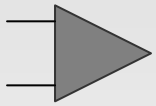
3 types

1. **Low Pass Filter (LPF)**
   - **Used to filter higher freq.**
2. **High Pass Filter (HPF)**
   - **used to filter low freq.**
3. **Band Pass Filter (BPF)**

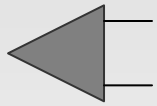
   -a combination of LPF and HPF

Contd.

- **Dual input (dual source – and + with respect to ground),**
  - **Used in audio equip. control circuits, medical equipment, etc.**
- **Single input**



Order of filters

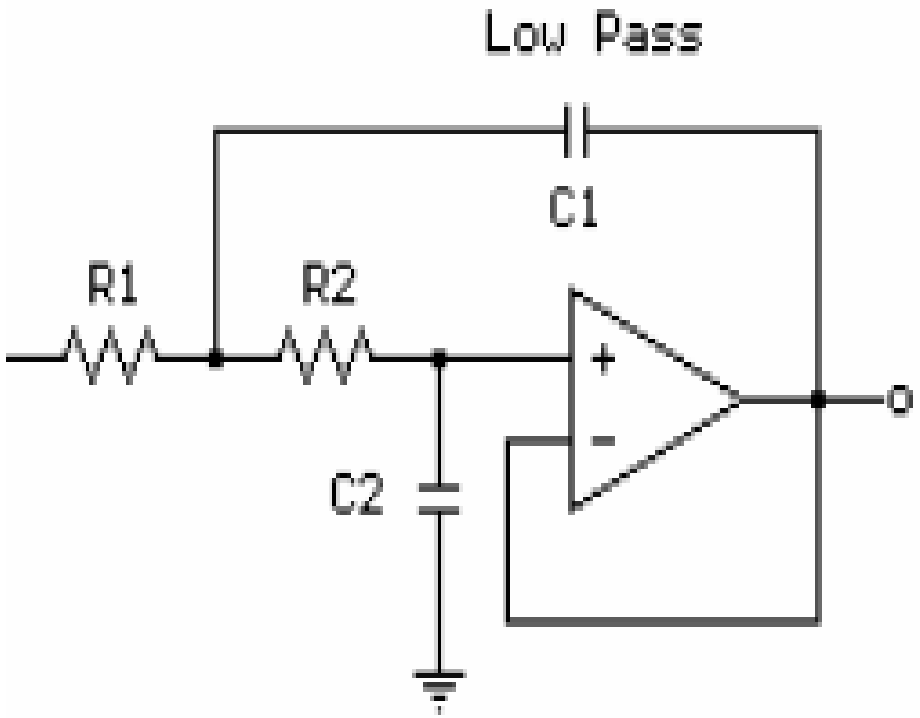


- First order
- Second order

Our examples show second order Filters.

- What was the order of the filter we used in lab?

LPF

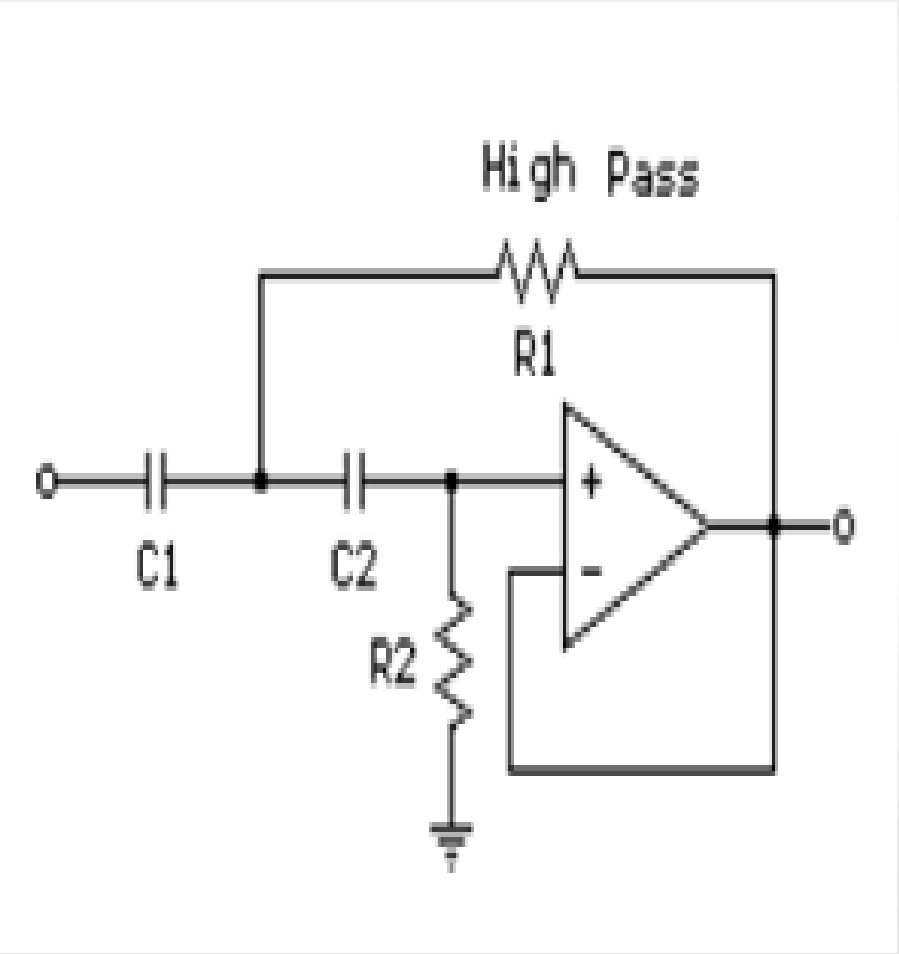


This filter is used to remove noise signals that are above the specified frequency.
The frequency range is given by the equation below

$$f = \frac{1}{2 \pi RC}$$

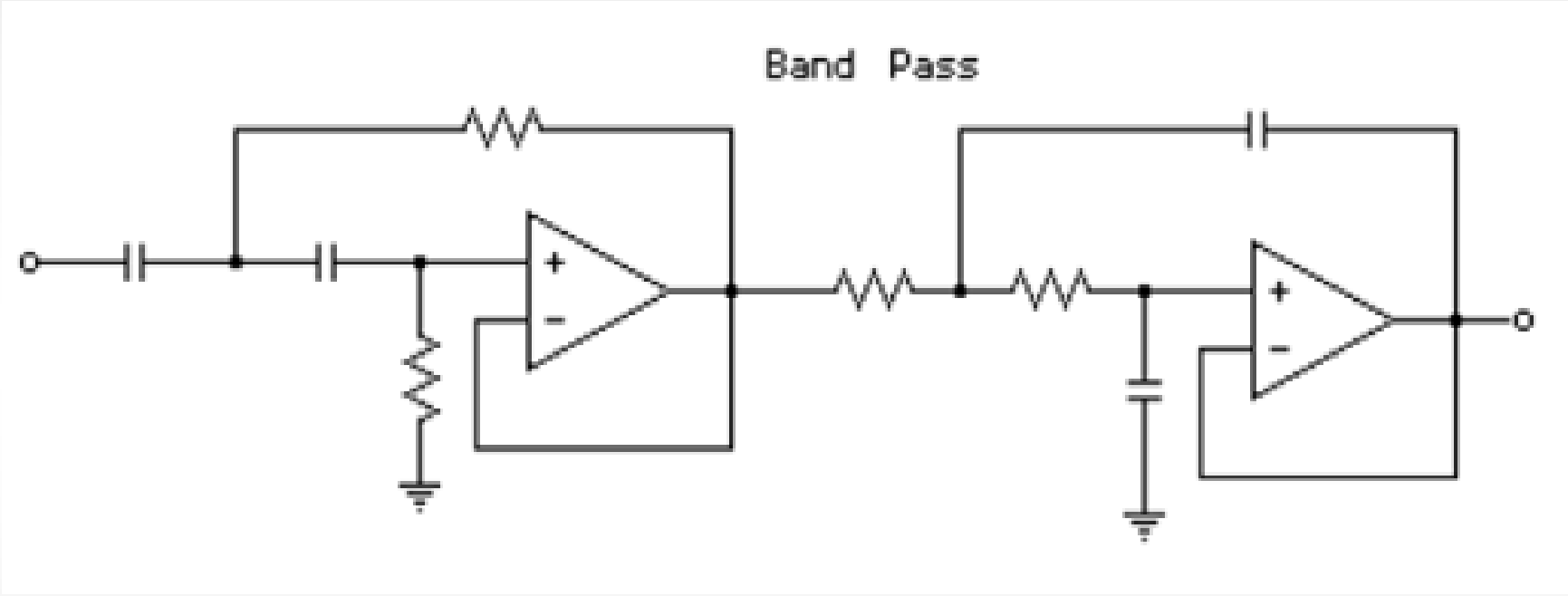
Where f=freq.
R=R2
C=C1

HPF



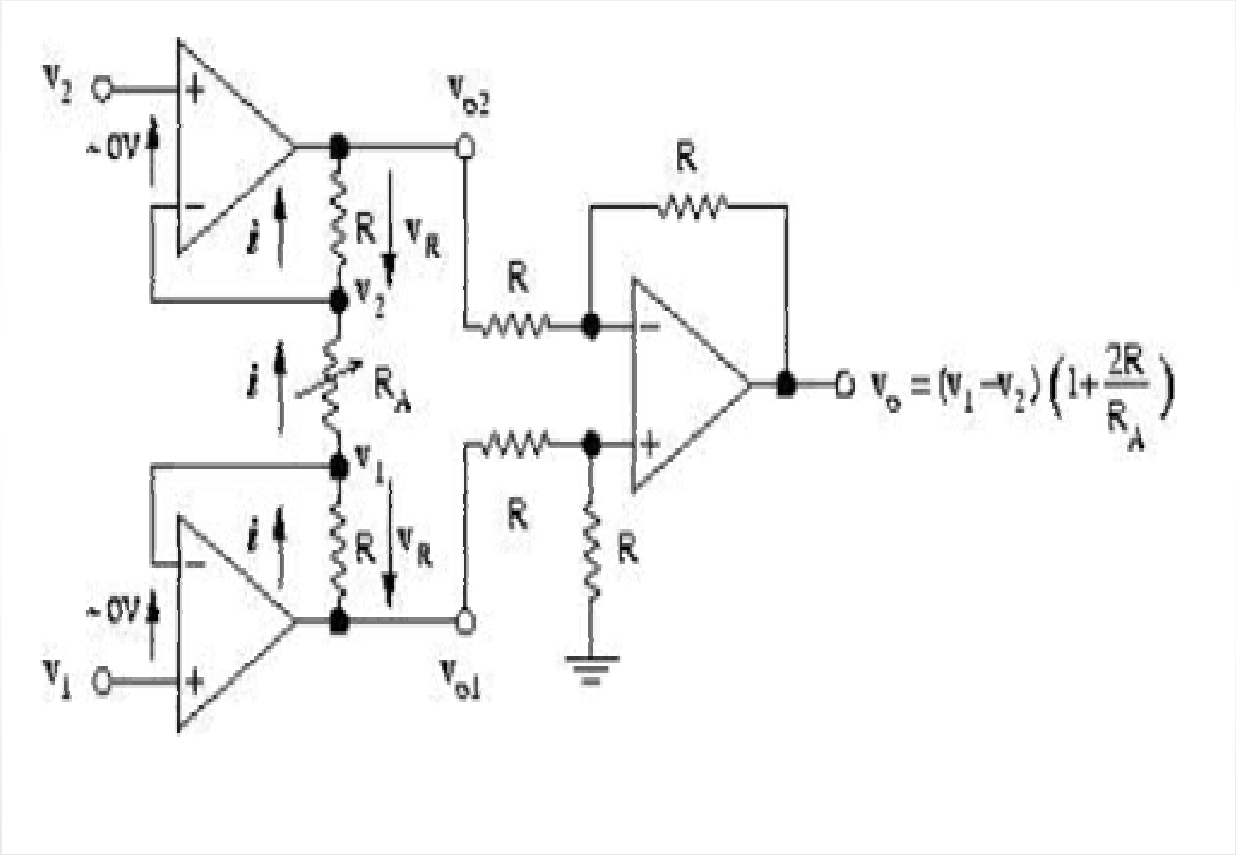
HPF is used to remove all freq. Below the specified freq. and it is Created by reversing the position of the capacitor and resistor In a LPF

BPF



This is a combination of the LPF and HPF. It allows for freq. within the range for the LPF and HPF.

Instrumentation OP Amp



This is used in Situations where output voltage needs to varied.

Analysis of instrumentation op amp

- $V_o = V_{o1} - V_{o2}$
- $V_{o1}=V_1+V_R$
- $V_{o2} =V_2 - V_R$
- $V_R = (V_1-V_2)R/R_A$
- $V_o= V_1-V_2+2V_R =(V_1-V_2)(1+2R/R_A)$

The use of filters

- Communications
- Removing noise from a power input
- Radio communications
- Infrared/ LED signals transm.
- Etc

Conclusions

- One major disadvantage
  - Distortion when dealing with really low freq. ranges

Conclusions contd.

- **Advantages**
  - **Useable in different industries**
  - **Signal and power amplification**
  - **Simple**
  - **Cheap and easy to build**
  - **Makes life easier**
  - **Math operations**

References

- www.electronics-tutorials.com
- www.play-hookey.com
- Alcitore, Histand Introduction to Mechatronics and Measurement Systems